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BELLCOMM, INC.
955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D. C. 20024

SUBJECT: Continued Use of Multiple Sites per Launch Opportunity in the Lunar Exploration Program - Case 340

DATE: March 4, 1969

FROM: N. W. Hinners

ABSTRACT

Consideration is given to the scientific implications of a continued multiple sites per monthly launch opportunity philosophy as contrasted with one site per opportunity. With the current list of tentative lunar exploration sites of wide longitudinal spread, there is reason to believe that a slightly more constrained version of the present multiple-site scheme can continue. Factors potentially restricting the desirability of the multiple site approach are: site dependent payloads; increased astronaut training requirements; and launch intervals, about 1/2 to 1/4 of ALSEP lifetime, which give little flexibility in establishing seismic networks.

(NASA-CR-106422) CONTINUED USE OF MULTIPLE SITES PER LAUNCH OPPORTUNITY IN THE LUNAR EXPLORATION PROGRAM (Bellcomm, Inc.) 10 p

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MEMORANDUM FOR FILE

I. INTRODUCTION

The first manned lunar landing attempt will be made at one of the five Apollo sites. The number, position, and spacing of the sites have been dictated by a combination of factors including: a desire to have several launch opportunities each month; KSC recycle times; free-return trajectories; adequate communications during lunar descent and ascent; optimum lighting at landing; and smooth topography at the sites and along the approach paths. This philosophy of first mission multiple sites has been acceptable for scientific purposes since a landing anywhere on the moon, with sample return, is a quantum jump over what we now have. Deliberations about sites for a second landing[1] have also been based on the multiple site philosophy with the proviso that one would not want to land at the first landing site again, that if the first landing is in the eastern mare, the second should be in the west (or vice-versa), and that we up-grade the science by biasing or relocating certain of the Apollo sites.

Deliberations on site selection for the third and subsequent missions have focused on the concept of a single site per opportunity.[1-7] The scientific rationale behind that logic is that there are specific features of interest which we desire to explore and that a mission would be tailor-made for that site. A contributory factor is the aversion among some scientists to a continued multiple site approach occasioned by a mistaken belief that multiple targets imply areas similar to the relatively featureless Apollo sites.

In order to accommodate the single site philosophy and the particular sites of interest, mission operations personnel have indicated that the free-return constraint could be relaxed and that ways to land over rough terrain could be devised. They further investigated ways in which they might keep a reasonably long KSC launch window, thus allowing for count-down holds and recycles, and still land at a specific site during the short optimum lighting period (∿6-15° sun angle). A promising possibility included planning an early launch and then using either variable translunar coast time, or multiple lunar orbits to use up time until the lighting at the site became favorable. During recent discussions of the Lunar Exploration Program, however, it has become apparent that the single site philosophy may be unduly constraining and that we should reconsider the scientific requirement for a single site approach. This holds particularly for missions flown before any changes are made to CSM and LM hardware which would allow significantly longer total mission times and longer time before LM landing. In this memo, therefore, I shall examine the factors which affect the scientific return from the exploration as they bear on the choice of the multiple or single site philosophy. Operational factors are not considered. One should keep in mind that these may be more constraining to a multiple site appraoch than scientific factors, e.g., reprogramming guidance computers.

II. SCIENTIFIC FACTORS AFFECTING SITE PHILOSOPHY

A. Site Assignments and Location

For purposes of this study, I have used the tentative site assignments and sequence shown in Table I and Figure I.* These sites have been used in most of the recent Lunar Program Reviews and include many recommended by the 1967 Summer Study of Lunar Science and Exploration[5] and by the Group for Lunar Exploration Planning.[1,6,7] From Figure I it is evident that there are longitudinal clumpings of sites which, all else being equal, would allow one to continue a follow-the-sun philosophy for many missions, albeit not with the degree of freedom offered by the 5 sites for the first and second landing. For example, eastern sites 4 and 5 give early launch window targets while western 2, 7, and 9 tie down the late window. More centrally located, sites 3, 6, 8, and 10 give mid-window targets. Granted, the tentative list of sites may well be changed but the total storehouse of sites of interest, for which we have good photography, exhibits a similar dispersion of site locations.

B. Sequential Dependency

Data Return

If one were convinced that the knowledge (primarily geochemical and geological) to be gained at site y depended

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*Sites of first and second landing arbitrarily selected to represent an eastern and western mare.

upon knowing what exists at site x, he would not want to consider x and y for the same mission. To my knowledge, no such requirement now exists for the sites considered. This should not be interpreted as meaning that there will be no mission feedback for it is highly probable that what we determine on a given mission will alter plans for the next mission no matter what the site. There is also a possibility, of course, that something extremely exciting will be found which will dictate a desire to go to a specific site on the next mission. Since that cannot be foreseen, we assign the possibility to the realm of real-time decision making in the future.

Site Dependent Payloads

The sites in Table I and Figure I were selected and time-sequenced on the basis of both scientific and operational considerations. Scientifically they represent excellent examples of the major classes of significant lunar features (mare, highlands) and processes (impact, volcanic, tectonic) and in a good exploration would be expected to provide the source of data sufficient to answer key questions about the origin and evolution of the moon.[1-7] From an operational viewpoint, they were selected first on the basis of an assumed requirement for available high resolution photography. They were then time-sequenced to fit assumed operational capabilities which were tied to specific schedules and to launch intervals of six months or longer. For example, sites 5-8 were associated with the Extended LM, with 3-7 days stay-time and mobility aids. Such a payload, at one time expected to be available in 1971, would amount to over-kill on sites 1-4, but would be less effective for sites 9 and 10 than dual launches. However, even with variable payloads, one could use a limited multi-site approach within certain site groupings, e.g., the same rover might be equally useful at Littrow and the Marius Hills or the same flyer at Tycho, Hyginus, and the Marius Hills.

The recent trend in the lunar planning has been towards less spacecraft and payload variability. The ultimate in that trend is 10 missions of identical capability in which case one can use any sequence of sites.

Instrument Networks

Certain experiments, especially the seismic, depend upon a widely spaced areal spread and over-lapping lifetimes for optimal information return. Figure 1 illustrates some of the potential network systems available assuming the sequential deployment of Apollo Lunar Surface Experiments Packages (ALSEP) at the sites of Table I. The particular seismic net available at a given time depends upon the launch interval, r, and individual seismometer lifetime, τ. It appears now that a one year seismometer life can be counted on with a reasonable expectation of two years, while launches may occur on 4 to 12 month centers. Assuming a two year life, a maximum launch interval is eight months if a net with sensible lifetime (>r) is to be established. Launches on 12 month centers would not allow one to establish a three station seismic triangulation net ($\eta = \frac{\tau}{r}$, where η = number of simultaneously operating stations), thus, for such intervals ($r \gtrsim 1/2\ \tau$) site sequencing is immaterial. A somewhat similar conclusion is reached for $r < 1/4\ \tau$. In this case stations have enough lifetime overlap so that the specific sequencing diminishes in importance. Let us consider now, though, the likely situation where $1/2\ \tau < r < 1/4\tau$ and where sequencing might be important.

Since the desired areal spread for a seismic net necessitates both a latitudinal and longitudinal separation, the first station can be established at any site, thus making it quite permissable to have multiple sites for that mission. Once the first station is established, the second should be emplaced relatively far away, either in latitude or longitude. If early sites are limited to the equatorial region, as seems likely, there is no choice - the separation must come in longitude but even here there is still potential for keeping more than one site per opportunity. With the establishment of two equatorial stations, however, (probably after three missions since the first lunar mission does not include deployment of a full capability long-life station) the need is changed to primarily one of latitudinal separation, with less sensitivity to longitude. Thus, for the third station, any of sites 5, 6, 7, and 9 would suffice, giving an option of sites $\sim 40°$ apart in longitude. Options for the fourth station would be almost as great.

In summary, it is evident that, with the present set of sites, establishment of a seismic net is compatable with a multi-site philosophy. Also evident is that a fast launch rate favors establishment of a good net and allows more station overlap. Alternatively, and more desirable from a scientific point of view would be to increase τ in advanced ALSEP's.

C. Astronaut Training

There is a limit to the number of sites for which a crew can train. The maximum number appears to be 3 or 4

Apollo-type mare sites where the prime requisites are for operational training for landing. It is noteworthy that the early sites are practically identical as regards general landing operations and topographic features. Later sites differ in two significant ways:

1. The approaches are topographically rougher and will presumably require more training for landing.

2. Each site is grossly different and includes specific points of interest. This will require site-dependent training for both landing and scientific operations. The latter increases in importance as staytime and mobility decrease, for then the astronaut must try to accomplish the proverbial maximum science in minimum time.

Discussions with astronauts and crew-training personnel indicate that it will be difficult for a given crew to train for more than two such sites. A program in which crews train for sites instead of missions could conceivably alleviate this problem, i.e., a pad hold or recycle would mean a crew change. More specifically, the prime crew could train for one set of sites and the back-up crew for another set. Potential problems dictating against extensive use of this approach are undesirable effects on astronaut morale and significant layout differences from one spacecraft to another. Relative to the latter, crews now train for a specific spacecraft. Both crew and spacecraft availability constraints would probably not permit more than one prime and back-up crew assignment per spacecraft. Even now the back-up crew does not receive the equivalent training of the prime crew, especially in the last month before launch.

III. CONCLUSIONS

With the current list of tentative lunar landing sites, there is reason to believe that a variation of the current multiple-sites/monthly launch opportunity philosophy can continue and not detrimentally affect the science accomplished. Factors which tend to decrease the desirability of the inherently more flexible multi-site approach are site-dependent payloads, astronaut training limitations, and launch intervals from about 1/2 to 1/4 of ALSEP lifetime.

N W Hinners

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Attachments
Table I
Figure I

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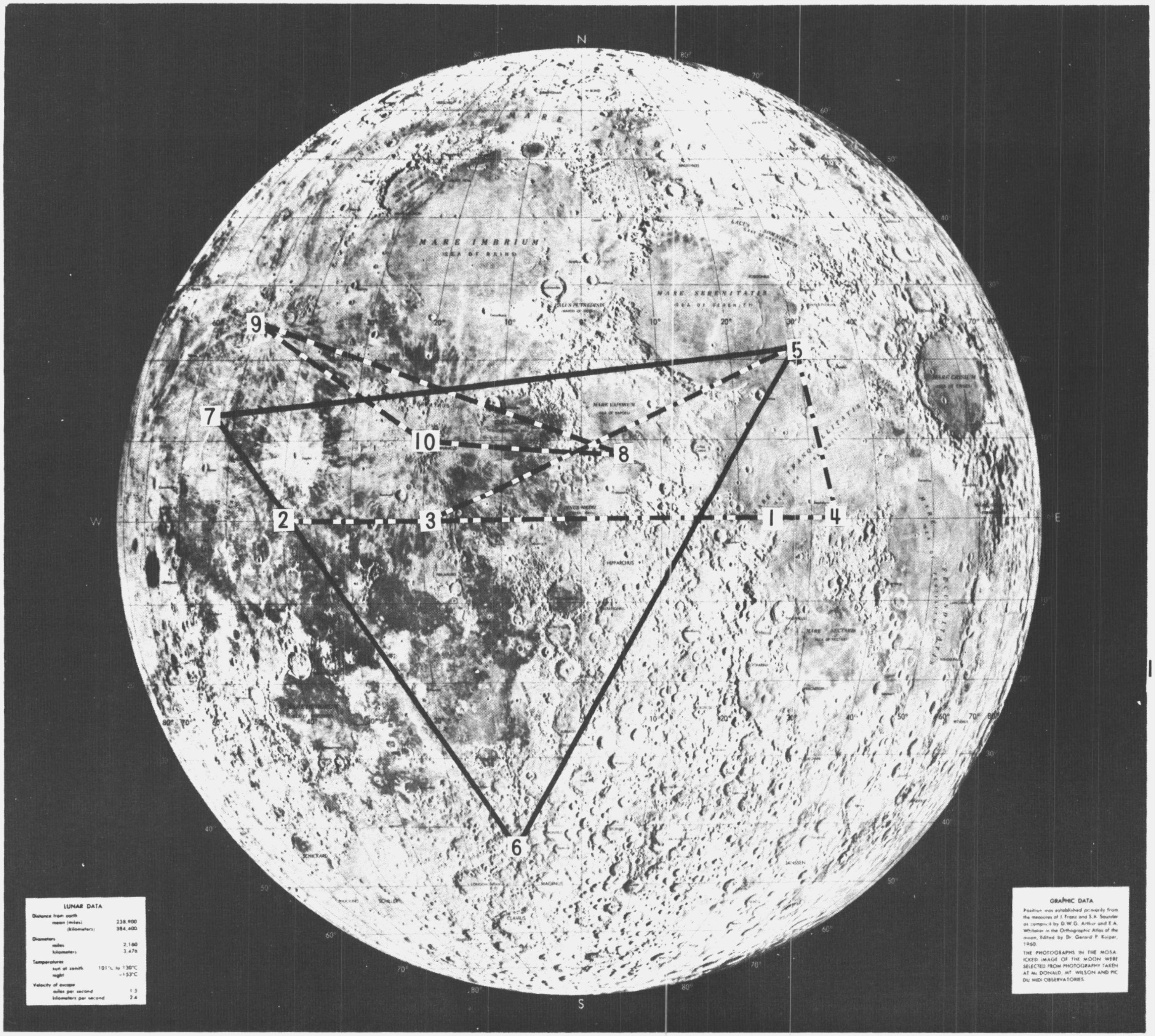
TABLE I

TENTATIVE MISSION ASSIGNMENTS

	SITE	MODE
1.	MARE (EASTERN)	"APOLLO"
2.	MARE (WESTERN)	"
3.	FRA MAURO	"
4.	CENSORINUS	"
5.	LITTROW	EXTENDED LM
6.	TYCHO	"
7.	MARIUS HILLS	"
8.	HYGINUS	"
9.	SCHRÖTER'S VALLEY	DUAL LAUNCH
10.	COPERNICUS	"



SITES

1. MARE (EAST)
2. MARE (WEST)
3. FRA MAURO
4. CENSORINUS
5. LITTROW
6. TYCHO
7. MARIUS HILLS
8. HYGINUS
9. SCHRÖTER'S VALLEY
10. COPERNICUS

FIGURE 1 - POTENTIAL LUNAR EXPLORATION SITES AND REPRESENTATIVE GEOPHYSICAL NETS

BELLCOMM, INC.

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From: N. W. Hinners

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